TITLE OF INVENTION

MODACRYLIC/COTTON/ARAMID FIBER BLENDS FOR ARC AND FLAME PROTECTION

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a blended yarn useful for the production of fabrics which possess arc and flame protective properties. This invention also relates to garments produced with such fabrics.

2. Description of Related Art

Individuals working near energized electrical equipment and emergency personnel who respond to incidents near electrical equipment are at risk from electrical arcs and flame hazards which could result from an arcing event. Electrical arcs are extremely violent events typically involving thousands of volts and thousands of amperes of electricity. Electrical arcs are formed in air when the potential difference (i.e. voltage) between two electrodes causes the atoms in the air to ionize and become able to conduct electricity.

Arc protective and flame resistant garments typically are uncomfortable to wear due to the poor moisture vapor transport of the protective fibers incorporated within. Individuals wearing protective apparel typically experience both tactile discomfort and heat stress as a result of the protective fibers incorporated in their protective garments.

United States Patent 5,208,105 to Ichibori et. al. discloses a flame retarded composite fiber blend comprising a halogen containing fiber having a large amount of an antimony compound and at least one fiber selected from the list consisting of natural fibers and chemical fibers. The fiber blend is woven into a fabric which is then tested for it Limited Oxygen Index as a measure of its flame resistance.

United States Patent 5,223,334 to Green discloses a fabric offering protection from radiant energy due to electrical arcs. Green makes no disclosure of the use of Modacrylic fibers within the blended yarn. Also,

Green does not disclose a protective fabric formed from yarns comprising less than 50 percent cotton.

What is needed is a yarn fabric and garment to provide a high level of protection when the material is exposed to an electrical arc and also flame resistance to protect the wearer from secondary effects.

SUMMARY OF THE INVENTION

This invention relates to a yarn for use in arc and thermal protection fabrics and garments comprising:

(a) 40 to 75 weight percent modacrylic fiber,

(b) 10 to 40 weight percent cotton fiber and

(c) 1 to 25 weight percent aramid fiber,

said percentages on the basis of components (a), (b) and (c).

The yarn is useful for incorporation into a thermally and arc resistant fabric and a garment especially suited for protecting workers against electrical arc. Furthermore the fabric and garment may provide resistance to break open, flame and abrasion.

DETAILED DESCRIPTION OF THE INVENTION

This invention relates to providing a yarn, fabric and garment to provide both improved arc protection and flame resistance. Fabrics and garments comprising flame resistant fibers of low tensile strength when exposed to the intense thermal stress of an electrical arc can break open exposing the wearer to additional injury as a result of the incident energy. Electrical arcs typically involve thousands of volts and thousands of amperes of electrical current. The electrical arc is much more intense than the incident energy such as from flash fire. To offer protection to a wearer a garment or fabric must resist the transfer to energy through to the wearer. It is believed that this occurs both by the fabric absorbing a portion of the incident energy and by the fabric resisting breakopen. During breakopen a hole forms in the fabric directly exposing the surface or wearer to the incident energy.

Yarns, fabrics and garments of this invention when exposed to the intense thermal stress of an electrical arc resist the transfer of energy. It is

believed that this invention reduces energy transfer by absorbing a portion of the incident energy and through charring allows a reduction in transmitted energy.

Yarns of this invention comprise a blend of modacrylic fiber, cotton fiber, and aramid fiber. Typically, yarns of this invention comprise 40 to 75 weight percent modacrylic fiber, 10 to 40 weight percent cotton fiber, and 1 to 40 weight percent aramid fiber. Preferably, yarns of this invention comprise 45 to 65 weight percent modacrylic fiber, 15 to 35 weight percent cotton fiber, and 5 to 30 weight percent aramid fiber. The above percentages are on the basis of the three named components.

By "yarn" is meant an assemblage of fibers spun or twisted together to form a continuous strand, which can be used in weaving, knitting, braiding, or plaiting, or otherwise made into a textile material or fabric

By modacrylic fiber it is meant acrylic synthetic fiber made from a polymer comprising primarily acrylonitrile. Preferably the polymer is a copolymer comprising 30 to 70 weight percent of a acrylonitrile and 70 to 30 weight percent of a halogen-containing vinyl monomer. The halogen-containing vinyl monomer is at least one monomer selected, for example, from vinyl chloride, vinylidene chloride, vinyl bromide, vinylidene bromide, etc. Examples of copolymerizable vinyl monomers are acrylic acid, methacrylic acid, salts or esters of such acids, acyrlamide, methylacrylamide, vinyl acetate, etc.

The preferred modacrylic fibers of this invention are copolymers of acrylonitrile combined with vinylidene chloride, the copolymer having in addition an antimony oxide or antimony oxides for improved fire retardancy. Such useful modacrylic fibers include, but are not limited to, fibers disclosed in United States Patent No. 3,193,602 having 2 weight percent antimony trioxide, fibers disclosed in United States Patent No. 3,748,302 made with various antimony oxides that are present in an amount of at least 2 weight percent and preferably not greater than 8 weight percent, and fibers disclosed in United States Patent Nos. 5,208,105 & 5,506,042 having 8 to 40 weight percent of an antimony compound.

Within the yarns of this invention modacrylic fiber provides a flame resistant char forming fiber with an LOI typically at least 28 depending on the level of doping with antimony derivatives. Modacrylic fiber is also resistant to the spread of damage to the fiber due to exposure to flame. Modacrylic fiber while highly flame resistant does not by itself provide adequate tensile strength to a yarn or fabric made from the yarn to offer the desired level of breakopen resistance when exposed to an electrical arc.

As used herein, "aramid" is meant a polyamide wherein at least 85% of the amide (-CONH-) linkages are attached directly to two aromatic rings. Additives can be used with the aramid and, in fact, it has been found that up to as much as 10 percent, by weight, of other polymeric material can be blended with the aramid or that copolymers can be used having as much as 10 percent of other diamine substituted for the diamine of the aramid or as much as 10 percent of other diacid chloride substituted for the diacid chloride of the aramid. Suitable aramid fibers are described in Man-Made Fibers--Science and Technology, Volume 2, Section titled Fiber-Forming Aromatic Polyamides, page 297, W. Black et al., Interscience Publishers, 1968. Aramid fibers are, also, disclosed in U.S. Pat. Nos. 4,172,938; 3,869,429; 3,819,587; 3,673,143; 3, 354,127; and 3,094,511. M-aramid are those aramids where the amide linkages are in the meta position relative to each other, and p-aramids are those aramids where the amide linkages are in the para position relative to each other. In the practice of this invention the aramids most often used are poly(paraphenylene terephthalamide) and poly(metaphenylene isophthalamide).

It is within the scope of this invention that a single type of aramid fiber can be employed. Illustratively, either a meta-aramid or para-aramid fiber can be used.

However, in a preferred mode both para-aramid and meta-aramid fibers are employed. An illustrative percentage is 20 to 40 weight percent para-aramid fibers and 60 to 80 weight percent meta-aramid fibers. The above percentages are on a basis of the aramid only. A preferred range

of these two aramids is 25 to 35 weight percent para-aramid and 65 to 75 weight percent meta-aramid.

Within yarns of this invention cotton fibers provide a flame resistant fiber that provides moisture transport within the yarn. Garments comprising cotton fibers improve the comfort of the wearer by wicking moisture away from the wearer. By allowing perspiration to wick away the heat stress to a wearer who is exerting themselves is reduced.

Additionally, to the yarn, fabric, or garment of this invention may be added an antistatic component such as steel fiber, carbon fiber, or a carbon coating to an existing fiber. The conductivity of carbon or a metal such as steel when incorporated in a yarn, fabric, or garment of this invention provides an electrical conduit to assist in dissipating the buildup of static electricity. Static electrical discharges can be hazardous for workers working with sensitive electrical equipment or near flammable vapors.

Yarns of this invention may be produced by any of the yarn spinning techniques commonly known in the art such as but not limited to ring spinning, core spinning, and air jet spinning or higher air spinning techniques such as Murata air jet spinning where air is used to twist staple fibers into a yarn. Typically the single yarns produced by any of the common techniques are then plied together to form a ply-twisted yarn comprising at least two single yarns prior to being converted into a fabric.

To provide protection from the intense thermal stresses caused by electrical arcs it is desirable that an arc protective fabric and garments formed from that fabric possess features such as an LOI above the concentration of oxygen in air for flame resistance, a short char length indicative of slow propagation of damage to the fabric, and good breakopen resistance to prevent incident energy from directly impinging on the surfaces below the protective layer.

Thermally protective garments such as firefighter turnout gear typically provide protection against the convective heat generated by an open flame. Such protective garments when exposed to the intense energy generated by an electrical arc can breakopen (i.e. an opening form in the fabric) resulting in the energy penetrating the garment and causing

severe injury to the wearer. Fabrics of this invention provide both protection against the convective heat of an open flame and offer increased resistance to breakopen and energy transfer when exposed to an electrical arc. The thickness of the fabric and overall weight of a protective garment such as a firefighter turnout coat typically worn can cause heat stress to a wearer by trapping body heat and perspiration next to the skin. Fabrics of this invention comprise a moisture transport fiber such as cotton within yarns of the fabric to provide a means for moisture due to perspiration to wick away from the wearer thus improving comfort and reducing heat stress.

Basis weight is a measure of the weight of a fabric per unit area. Typical units include ounces per square yard and grams per square centimeter. The basis weights reported in this specification are reported in ounces per square yard (OPSY). As the amount of fabric per unit area increases the amount of material between a potential hazard and the subject to be protected increases. An increase in the basis weight of a material suggests that a corresponding increase in protective performance will be observed. An increase in basis weight of fabrics of this invention results in increased breakopen resistance, increased thermal protection factor, and increased arc protection. Basis weights of fabrics of this invention are typically greater than about 8.0 opsy, preferably greater than about 8.7 opsy, and most preferably greater than about 9.5 opsy. It is believed fabrics of this invention with basis weights greater than 12 opsy would show increased stiffness and would thereby reduce the comfort of a garment produced from such fabric.

Char length is a measure of the flame resistance of a textile. A char is defined as a carbonaceous residue formed as the result of pyrolysis or incomplete combustion. The char length of a fabric under the conditions of test of ASTM 6413-99 as reported in this specification is defined as the distance from the fabric edge, which is directly exposed to the flame to the furthest point of visible fabric damage after a specified tearing force has been applied. Preferably fabric of this invention have a char length of less than 6 inches and preferably less than 4.5 inches.

Fabrics of this invention may be used as a single layer or as part of a multi-layer protective garment. The yarns of this invention may be present in either the warp or fill of the fabric. Preferably the yarns of this invention are present in both the warp and fill of the resulting fabric.

TEST METHODS

Abrasion Test

The abrasion performance of fabrics of this invention is determined in accordance with ASTM D-3884-01 "Standard Guide for Abrasion Resistance of Textile Fabrics (Rotary Platform, Double Head Method)".

Arc Resistance Test

The arc resistance of fabrics of this invention is determined in accordance with ASTM F-1959-99 "Standard Test Method for Determining the Arc Thermal Performance Value of Materials for Clothing". Preferably fabrics of this invention have an arc resistance of at least 0.8 calories and more preferably at least 1.2 calories per square centimeter per opsy.

Grab Test

The grab resistance of fabrics of this invention is determined in accordance with ASTM D-5034-95 "Standard Test Method for Breaking Strength and Elongation of Fabrics (Grab Test)".

Limited Oxygen Index Test

The limited oxygen index (LOI) of fabrics of this invention is determined in accordance with ASTM G-125-00 "Standard Test Method for Measuring Liquid and Solid Material Fire Limits in Gaseous Oxidants".

Tear Test

The tear resistance of fabrics of this invention is determined in accordance with ASTM D-5587-03 "Standard Test Method for Tearing of Fabrics by Trapezoid Procedure".

Thermal Protection Performance Test

The thermal protection performance of fabrics of this invention is determined in accordance with NFPA 2112 "Standard on Flame Resistant Garments for Protection of Industrial Personnel Against Flash Fire".

Vertical Flame Test

The char length of fabrics of this invention is determined in accordance with ASTM D-6413-99 "Standard Test Method for Flame Resistance of Textiles (Vertical Method)".

The term thermal protective performance (or TPP) relates to a fabric's ability to provide continuous and reliable protection to a wearer's skin beneath a fabric when the fabric is exposed to a direct flame or radiant heat.

Limited Oxygen Index (LOI)

From ASTM G125 / D2863

The minimum concentration of oxygen, expressed as a volume percent, in a mixture of oxygen and nitrogen that will just support flaming combustion of a material initially at room temperature under the conditions of ASTM D2863.

To illustrate the present invention, the following examples are provided. All parts and percentages are by weight and degrees in Celsius unless otherwise indicated.

EXAMPLES

Modacrylic/Cotton/Aramid Fabric

Example 1

A comfortable and durable fabric was prepared having in the both warp and fill of ring spun yarns of intimate blends of Nomex® type 462, Kevlar® 29, Modacrylic and Cotton. Nomex® type 462 is 93% of poly(m-phenylene isophthalamide)(MPD-I), 5% of poly(p-phenylene terephthalamide)(PPD-T) and 2% of static dissipative fibers (P-140 from

DuPont), Modacrylic is ACN/polyvinylidene chloride co-polymer with 15% antimony (known as Protex®M), and Kevlar® 29 is poly(p-phenylene terephthalamide)(PPD-T).

A picker blend sliver of 10 wt.% of Nomex® type 462, 10 wt.% of Kevlar® 29, 55 wt. % of Modacrylic and 25 wt. % of cotton was prepared and processed by the conventional cotton system into a spun yarn having twist multiply 3.7 using a ring spinning frame. The yarn so made was 24.6tex (24 cotton count) single yarn. Two single yarns are then plied on the plying machine to make a two-ply yarn. Using similar process and same twist and blend ratio, a 32.8tex(18 cotton count) yarn was made for using as fill yarn. The yarns were then two-plied to form a ply yarn.

The Nomex®/Kevlar®/Modacrylic/Cotton yarns were used as the warp and fill in a shuttle loom in a 3x1 twill construction. The greige twill fabric had a construction of 24ends x 15 picks per cm (60 ends x 39 picks per inch), and basis weight of 271.3 g/m^2 (8 oz/yd^2). The greige twill fabric prepared as described above was scoured in hot water and dried under low tension. The scoured fabric was then jet dyed using basic dye.

Example 2

A comfortable and durable fabric was prepared having in the both warp and fill of ring spun yarns of intimate blends of Nomex® type 462, Kevlar® 29, Modacrylic and Cotton. Nomex® type 462 is 93% of poly(m-phenylene isophthalamide)(MPD-I), 5% of poly(p-phenylene terephthalamide)(PPD-T) and 2% of static dissipative fibers (P-140 from DuPont), Modacrylic is ACN/polyvinylidene chloride co-polymer with 15% antimony (known as Protex®M), and Kevlar® 29 is poly(p-phenylene terephthalamide)(PPD-T).

A picker blend sliver of 10 wt.% of Nomex® type 462, 10 wt.% of Kevlar® 29, 45 wt. % of Modacrylic and 35 wt. % of cotton was prepared and processed by the conventional cotton system into a spun yarn having twist multiply 3.7 using a ring spinning frame. The yarn so made was 24.6tex (24 cotton count) single yarn. Two single yarns are then plied on the plying machine to make a two-ply yarn. Using similar process and same twist, a 32.8tex(18 cotton count) yarn with blend of Nomex® type

462/Modacrylic at 50/50 ratio was made for using as fill yarn. The yarns were then two-plied to form a ply yarn.

The Nomex®/Kevlar®/Modacrylic/cotton yarn was used as the warp and Nomex®/Modaxrylic yarn as the fill in a shuttle loom in a 3x1 twill construction. The greige twill fabric had a construction of 23 ends x 16 picks per cm (58 ends x 40 picks per inch), and basis weight of 264.5 g/m^2 (7.8oz/yd^2). The greige twill fabric prepared as described above was scoured in hot water and dried under low tension. The scoured fabric was then jet dyed using basic dye.

The following Table illustrates measured properties of Examples 1 and 2.

	Example 1	**Example 2**
Fabric Composition		
Fabric Construction	**2x1 twill**	**2x1 twill**
Basis Weight (opsy)	**6.7**	**6.7**
Char Length (in) WarpxFill	**4 x 4**	**3.3 x 3.6**
TPP Value (cal/cm^2)	**11.8**	**12.5**
Grab Strength (lbf) WarpxFill	**100x96**	**118x89**
Trap Tear (lbf) WarpxFill	**13.6x11.7**	**13.8x10.8**
Taber Abrasion (Cycles) CS-10/1000 g	**352**	**317**